TO DEVELOP CONCRETE MIX BY USING SAND OF FINENESS MODULUS LESS THAN 2.4

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Abstract

Concrete’s compressive strength is dependent on the shape and gradation of both types of aggregate and how strongly the aggregates are bonded together. According to ACI provisions the Fineness modulus (FM) of sand to be used in concrete mix is in range of 2.4 to 3.0. But in Pakistan the sand available is much finer having FM around 2.0. So, In order to utilize the available sand in concrete mix design, we need to develop practice to use such type of sands in our concrete mix design. Through this project, we tried to find out the particular values of bulk volume of coarse aggregate against FM 2.0 and 2.2 of sand, for specific nominal maximum sizes of coarse aggregate i.e. 1/2” and 1”, while keeping water to cement ratio fixed at 0.55. The compressive and tensile strengths along with the slump values are considered as standard parameters as a practice when different combinations of coarse aggregates i.e.1/2” and 1” and sand with F.M of 2.0 and 2.2 are incorporated in concrete mix design.

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CHAPTER 1

INTRODUCTION

1.1 Background

Concrete, due to its universal properties has been a major construction material throughout the world for many years now. Besides having several different properties like fire resistance, versatility and affordability, the ability of concrete to be molded in any shape and its compressive strength are the predominant properties that distinguish it from other similar materials.

The quality (strength and workability) of concrete lies in the way its constituents are bonded with each other. There are many factors that play a key role in making sure that the concrete components are blended together in a way to achieve high strength along with definite workability. Coarse aggregate is no doubt the load bearing member of concrete but, the role played by fine aggregate is of immense importance. The shape and particle size distribution of fine aggregate significantly governs the behavior of concrete. ACI has provided gradation envelopes for aggregate selection in order to prepare the concrete mix design. According to ACI provision 211.1, the fine aggregate to be selected should have the fineness modulus (FM) in range of 2.4 to 3.0.

The importance of using the right type and quality of aggregates cannot be overemphasized. Use of finer sands can make the mix uneconomical, by increasing the cement demand, whereas, very uniform sized coarse aggregates can produce severe and less workable mixtures. In general, aggregates that do not have a large deficiency or excess of any size and give a smooth grading curve will produce the most satisfactory results. So, the balance between the aggregate sizes and their quantities is very necessary. The fine and coarse aggregates constitute 60% to 75% of the concrete volume (Kozul 1995) and strongly influence the concrete's freshly mixed and hardened properties, mix proportions, and economy.

Sand is one of the key components of concrete and acts as a filler material and is used in much larger quantity than cement. Its coarseness or fineness greatly influences the water demand of concrete and consequently the workability and strength of concrete. The properties of a specific concrete mix will be determined by the grading, quantity and type of filler material used to form the concrete mix.

In Pakistan, the coarser sand deposits are very few. The sands of Kibla bandi, Sakhi sarwar and Lawrencepur are some of the fewer coarser sand deposits (Tahirkheli 1981). Mostly finer sand is easily available in Pakistan. So, the prospect we are trying to carry is to utilize this finer sand and to come up with a workable concrete having targeted strength while keeping water to cement ratio fixed.

1.2 Problem Statement

Fineness modulus (FM) of an aggregate represents that how coarse or fine it is. For sand, its value generally ranges from 2.0 to 4.0 (Whole building design guide 1980). Finer the sand is, lower is its fineness modulus. In ACI code (Provision 211.1), the recommended value of FM of sand ranges from 2.4 to 3.0. As discussed earlier, in Pakistan, the coarser sand deposits are fewer and they will deplete with the passage of time and we would be only left with the sand deposits having finer sand with FM less than 2.4. So, there is a need to utilize the available sand deposits which are much finer. While using finer sands the core properties of concrete like workability, cohesiveness, compressive strength will change altogether. The workability and cohesiveness of concrete depends upon how strong coarse and fine aggregate are bonded together. Bonding between aggregates affects the density and density of concrete is directly proportional to the strength of concrete. Research has shown that density of concrete increases as we use coarser sand (Espino 1966).

Finer sand has more surface to volume ratio, therefore it requires more water for its surface wetting. While incorporating finer sand in mix design we need to make some adjustments so that we can achieve the balance between coarse and fine aggregate. To control the water demand, we need to increase the bulk volume of coarse aggregate (lesser specific surface area) that eventually reduces the quantity of fine aggregate .Higher fines increase water demand, higher water demand translates in to using more cement in order to keep water to cement ratio fixed. Balance is very necessary to make sure that both materials blend together in a denser form and give more strength. Therefore, during mix design calculations, the bulk volume of a specific sized coarse aggregate is selected against a particular FM of sand. Through this project, we are trying to incorporate through experimentation, and by keeping in view all the above discussed aspects, the values of bulk volume of specific sized coarse aggregate which will give maximum compressive strength with a targeted slump, against sand having FM 2.2 and 2.0.

ACI have some limitations on FM of sand in mix design and sand available in Pakistan do not fall under their specified range and that's the reason we cannot even design concrete incorporating finer sand.

1.3 Objective

Following different objectives will be achieved after the completion of this project.

- To utilize the locally available finer sand resources in Pakistan in concrete mix design.
- To Investigate the Variation in Bulk Volume of coarse aggregate using finer sand.
- To Study the effect of lower FM of fine aggregate on concrete strength.
- To come out with the best possible combination of concrete ingredients for a particular volume of a definite coarse aggregate size against a specified FM of sand.

By achieving these objectives we will be able to utilize locally available sand resources of Pakistan in our mix designs which will definitely help in economizing our mix design. We will also investigate the variation in bulk volume of coarse aggregate as the finer sand effects its value. The effect of sand having lower FM on concrete strength and the relationship of strength with the density of concrete will also be studied. Last objective is to come up with the best possible blend of coarse and fine aggregates against their specified volumes and sizes while keeping water to cement ratio fixed.

1.4 Scope

- Aggregates with the nominal maximum size of 1" and ½ "will be used.
- Sand with FM of 2.2 and 2.0 will be used.
- Specimens will be tested on compressive and tensile strengths, workability and segregation.
- 28 days compressive strength will be taken into consideration.

CHAPTER 2

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LITERATURE REVIEW

Overview

The use of finer sand in concrete will lead to several different problems that are highlighted in the problem statement of the project. Literature review was done in order to address these problems. The effect of all major concrete components on its strength and other properties like durability, workability and porosity are discussed in this chapter. Through literature review the methodology of project was envisaged that is discussed in detail in chapter 3.

2.1 Fineness Modulus

The Fineness modulus (FM) is an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing the sum by 100.

Fineness modulus is the gradation description of the sample of an aggregate. It tells us that how coarse or fine is the aggregate which we are going to incorporate in our mix design More fineness modulus value indicates that the aggregate is coarser and small value of fineness modulus indicates that the aggregate is finer. Fine aggregate affects many concrete properties, including workability and finish ability. Very coarse or quite fine sand produce concrete mix of poor quality. Coarse sand produces concrete mixes prone to segregation and also help in development of micro cracks due to improper cohesion with the coarse aggregate (Noumowe, 2009). Due to greater surface area fine sands require more quantity of water to achieve the desired concrete workability and may also require higher amount of cement contents. Hence, values of FM can be used as a technical way to balance coarse aggregate with fine aggregate in the mix to achieve the required grading. Therefore FM of both coarse and fine aggregates have to be adjusted in a way that they balance out the water cement demand and hence achieve a compact blend.

2.2 Gradation

As discussed earlier, aggregates constitute 60% to 75% (Kozul 1997) of the entire volume of concrete mix, still very less consideration is given in controlling the proper aggregate gradation so that optimizes concrete can be form. Compactness and workability of concrete mix is directly affected by the improper blend of aggregate which consequently affects the cement and water demand. It also has negative influence over concrete properties like flexural strength and permeability (Kozul 1997). Durability and cohesion of concrete is also affected by the improper blend of aggregates. The gradation of aggregates being used in mix design is the most important factor that will define the compressive strength of the concrete formed. The Density of concrete is dependent upon its packing which can be achieved by properly grading both coarse and fine aggregate. Proper gradation of aggregates being used in concrete mix will lead to a good blend between the constituents of concrete that surely will affect its compressive strength. The American Society for Testing Materials (ASTM) specification for the grading and quality of aggregates for normal weight concrete is defined by Designation: C 33. There are seven different gradation standards based upon different sieve numbers for fine aggregate gradation.

2.2.1Grading Requirement for Fine Aggregates from ASTM Designation C 33

Sieve Sizes	Percent Passing
3/8 inches	100
No. 4	95-100
No. 8	80-100
No. 16	50-85
No. 30	25-60
No. 50	10-30
No. 100	2-10

Table-1 Fine Aggregates grading ASTM Designation C 33

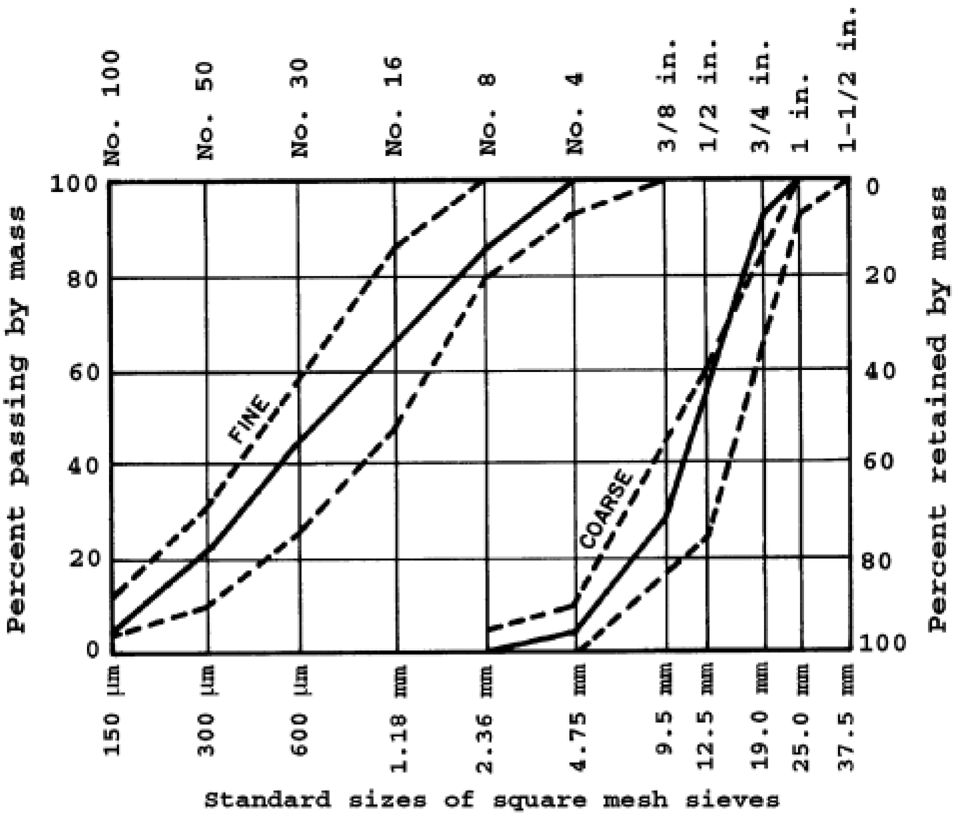

Fig-1 ASTM requirements for coarse and fine aggregate

So, the fine aggregate being used in mix design must follow the above mentioned grading requirements of the ASTM.

For the coarse aggregate grading requirements of ASTM C 33 allow variety of grading sizes for a given maximum-size coarse aggregate. There can be a variation in the size of coarse aggregate in a reasonable limit without any noticeable effect on cement and water requirement of a mixture as long as the combination of fine aggregate to total aggregate produces workable concrete (Popovics 1997). Our mixture ought to have suitable workability if there is wide deviation in the grading of coarse aggregate. In order to meet this criteria the gradation of coarse aggregate is done carefully by allowing certain percentage passage through each sieve.

2.2.2 Grading Requirement for Coarse Aggregates (ASTM C 33, Size No. 5)

For a particular aggregate size, ASTM has set some percentage passing requirements. For example, in this table the percentage passing requirements for maximum aggregate size of 1" are given in the following table:

Sieve Sizes (in)	Percent Passing
1.5	100
1	90-100
¾	25-55
½	0-10
3/8	0-5

Table-2 Grading requirements for coarse aggregate for nominal maximum size of 1 inch.

2.3 Relation of Bulk volume with fineness modulus

Bulk volume of an aggregate consists of total volume of the aggregate. It comprises of volume of impervious portion of the aggregate particles as well as the volume of the penetrable voids in the particles. For an aggregate the bulk volume is the total volume of water displaced by that particular aggregate in a SSD (saturated surface dry) condition. (Brady. 1960)

ACI 211.1

Bulk Volume of Coarse Aggregate

Maximum size of aggregate, mm	(in.)	Fineness modulus of sand			
		2.40	2.60	2.80	3.00
9.5	(3/8)	0.50	0.48	0.46	0.44
12.5	(1/2)	0.59	0.57	0.55	0.53
19	(3/4)	0.66	0.64	0.62	0.60
25	(1)	0.71	0.69	0.67	0.65
37.5	(1 1/2)	0.75	0.73	0.71	0.69
50	(2)	0.78	0.76	0.74	0.72
75	(3)	0.82	0.80	0.78	0.76
150	(6)	0.87	0.85	0.83	0.81

Table -3 ACI 211.1

Density of concrete is dependent on the fact that how well its constituents are proportionated with respect to each other to get maximum packing. Therefore, during mix design calculations, ACI has recommended a table in the provision 211.1 in which the bulk volume of a particular sized coarse aggregate is calculated against a particular FM of sand.

As we can observe that with decrease in fineness modulus of sand (against any particular coarse aggregate size) the value of bulk volume of coarse aggregate is increasing. This is dependent on the fact that increase in volume of one constituent leads to relative decrease in the volume of the other in such a way that there exists a balance between both the constituents. As the FM of sand decreases, the overall surface area of concrete increases which increases the water demand. So, in order to balance the water demand we have to increase the bulk volume of coarse aggregate (lesser specific surface area) and reduce the quantity of fine aggregate. Balance is very necessary to make sure that both materials blend in a denser form and give more strength.

By carefully observing the trend of the table we can comprehend that ACI has adjusted the values of FM of sand and the bulk volumes of coarse aggregate in such a way that their weighted average fineness modulus remains constant across the table for a particular size of coarse aggregate against different fineness modulus of sand. This forms the basis of our research methodology, which is discussed in detail in chapter no 3.

2.4 Interfacial Transition Zone (ITZ)

Through experimentation it has been found that interfacial transition zones (ITZ's) exist in the region between coarse and fine aggregate particles and cement paste. This can be related to the fact that the cement paste physically is grainy itself. A region of higher porosity is formed around the aggregate which comes into play when cement particles meet the aggregate giving birth to the phenomenon called “Wall Effect” (Garboczi 1996). This is due to the packing limitation offered by the larger aggregate size in comparison to the cement particles. Moreover larger the aggregate size, lesser is the thickness of ITZ. The thickness of ITZ is based on the average particle size of cement and not on the aggregate size. The average grain size of mostly available cements is nearly 10-30 micrometers (Jensen 1999), which is usually the width one associates with ITZ's.

2.4.1 Effect on properties

The Interfacial Transition Zone has a remarkable impact on the overall strength and other related properties of concrete mixture as it acts as the weakest link in the chain as compared to the coarse aggregate and mortar (Garboczi 1996). That is why if the ITZ has lesser stiffness and lower strength, it will have a direct impact on the properties of concrete mixture rather than cement paste only. We observe an increment in the volume of ITZ if there is increment of large aggregate particles along with the average median size of the aggregate. This explains why usually the overall concrete strength decreases due to increase in these factors. It also has been observed that the bulk paste is less pervious as compare to ITZ that is because ITZ has greater porosity. In a concrete we usually expect the ITZ to create larger porous phase throughout the bond structure .This results in increased permeability of concrete as large as 1000 times greater as compare to sheer cement paste (Zimmerman 2009). As the permeability of concrete increases, its durability decreases. That is why it affects the characteristics of concrete to a great deal. Our main focus of concern is shrinkage, creep, compressive strength.

2.5 Factors Affecting Concrete Performance

The performance of concrete is highly affected by the physical and chemical properties of its individual constituents. Its strength, workability, durability and other properties are affected significantly by the type of constituents being used.

2.5.1 Effect of Aggregate

Aggregate being the load bearing member of concrete has a marked effect on the concrete's performance. The gradation, surface texture, shape and several different properties of aggregate accumulatively govern concretes behavior.

2.5.1.1 Strength

Due to better bonding with the cement paste the angular and rough aggregates will exhibit more strength. Moreover the voids between angular aggregates are lesser as compare to rounded aggregates, so they provide more strength. Surface texture losses its significance in the latter ages of concrete once the chemical interaction between cement paste and aggregate gets effective (Tsiskrel 1970) . The maximum size of aggregate also affects the concrete strength. Large aggregate particles are subjected to high stress concentration when compressive loading is applied. Large sized particles form interfacial transition zones due to which more micro cracks appear as compare to small aggregate particles.

2.5.1.2 Workability

The workability of concrete mixture is highly affected by the shape, gradation, porosity, and surface texture of aggregates. The workability of concrete mixture increases if the aggregates are spherical and smooth-edged with plane surface on the other hand, we observe decrease in workability when angular, flaky, abrasive aggregates are used. And this decrease in workability results in segregation. Appropriate amount of well-graded aggregates should be used in order to achieve the required workability because the smoothness or abrasiveness or aggregate particle will affect the overall workability of a concrete mixture (Punkki 1996). The smaller aggregate particles have relatively larger surface area which results in increases water demand for their surface wetting. Hence we can conclude that the size, shape as well as the texture of the aggregate particles will affect the overall workability of a concrete mixture.

2.5.1.3 Durability

Durability will be increased by using larger maximum aggregate size since the cement paste content which is under physical or chemical attack is decreased in this case. However, when concrete is subjected to freeze-thaw condition, reducing the aggregate size will increase durability. Hard, dense and strong aggregate have strong wear resistance so their use will improve ductility (Kozul 1997). Alkaline nature of cement paste may cause a chemical reaction with the silica present in the aggregate. Vigorous reaction takes place between silica and alkaline cement paste which is very harmful for the concrete and it remarkably reduces the overall strength and durability of concrete due to cracking and staining.

2.5.2 Effect of Water to Cement Ratio

W/C ratio affects the workability of concrete and thus should be taken into careful consideration. Also, if the ratio exceeds the normal value, segregation of concrete occurs and the coarse aggregate settles at the bottom, thus affecting the strength of concrete greatly.

2.5.2.1 Strength

The strength at any particular age is dependent on the w/c and the degree to which the cementitious materials have hydrated. The relation between the strength and water to cement ratio can be clearly seen. Strength keeps on decreasing as the water to cement ratio is increased.

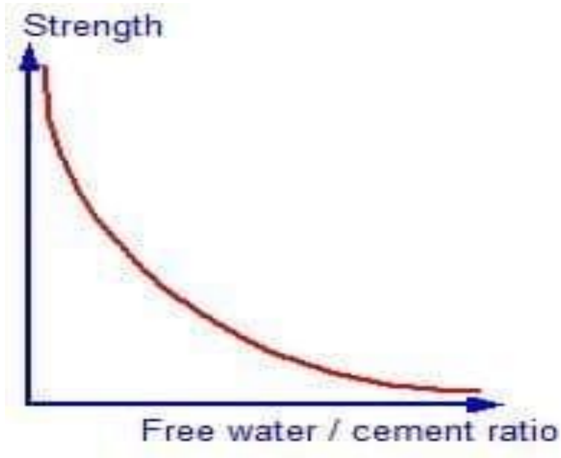

Figure-2 Strength vs w/c

The permeability in the interfacial transition zone present between the cement paste and aggregate is effected by the water cement ratio (Elsevier 2007). The porosity of cement paste is also affected by it. Strength decreases with increasing w/c because the porosity increases. Thus, to increase strength, reduce w/c. It is more efficient to reduce the water content than to use more cement. Water and cement ratio must be selected keeping in mind both the workability as well as the desired strength of concrete.

The Figure clearly explains the inverse relation between the strength and water to cement ratio. The higher the water/cement ratio, the greater the initial spacing between the cement grains and greater the volume of voids not filled by hydration products. We can change the water cement ratio according to the requirement of the structure and the construction type.

2.5.2.2 Durability

The durability decreases with the increment in the cement amount for a given water to cement ratio. That is because both chloride penetration and shrinkage increase by increasing the cement content (Nallathambi 1984). Concrete will be prone to cracking due to increasing shrinkage which will shorten the life of concrete thus decrease its durability. Water to cement ratio is an imperative factor for durability of concrete. With the decrease in water to cement ratio we can observe a decline in permeability of cement paste which makes concrete mixture less permeable i.e. the water percolation along with compounds like chlorides and sulphates, through the mixture is decreased to a great extent. This results in increased durability of concrete mix. If the durability is not the governing factor then we ought to choose water to cement ratio according to compressive strength requirement.

2.5.3 Effect of Sand

Sand acts as filler material in concrete. Its fineness directly affects the strength and workability of concrete. It reduces Shrinkage and cracking of concrete.

2.5.3.1 Strength

The main purpose of fine aggregate is to fill the voids between coarse aggregate. The gaps in coarse aggregate are filled by the sand. This helps in dense packing of concrete and consequently the compressive strength of concrete increases. The gaps in sand are then filled by the cement. Even after adding water there remains some voids in the mixture which are removed by vibrations (Wang 2000). Coarser sand provides more strength to concrete as compare to fine sand.

2.5.3.2 Shrinkage

It reduces shrinkage and cracking of concrete. Stiffer the concrete is, lesser is the drying shrinkage. Since sand acts as a filler and helps in achieving more dense concrete by removing voids between aggregates so it helps in reducing drying shrinkage of concrete (Petrov 2007).

2.5.4 Cement Content

If we donot vary the volume of coarse aggregate and the cement amount as compare to that of sand then there will be an increase in overall effective surface area of the solid. This will result in greater water demand. The water demand will stay the same for the constant workability if the surface area of the solids has increased. If cement content increases while the water content remains the same then, the water cement ratio will decrease. The strength of the concrete will increase if the water to cement ratio decreases. An increase or decrease in cement content affects the workability and strength. If the cement content is increased then it will have a minute effect on water demand and will reduce the water to cement ratio by only a small amount which consequently will decrease the strength of concrete mixture (Okundi 1998). Hence, we can conclude that if we increase the cement content for a given workability there will be an increase in overall strength of concrete mixture.

2.5.5 Age of concrete

The rate of hydration depends upon the surrounding temperature as well as on the water provided for its hydration. If we continuously provide water for the hydration of concrete then the age of concrete will be increasing. But, the rate of increase in strength of concrete decreases as it is in the early days. Most of the strength is gained during the first 28 days of hydration which caters for the majority of practical applications of concrete.

2.5.6 Compaction of concrete:

Due to insufficient compaction of freshly made concrete, the air is trapped in the mixture which results in the reduction of overall strength. According to research for every 10% air entrapped the strength of concrete reduces about 30% to 40% (Elsevier 2007). Therefore we can say that compaction of concrete is one of the governing factors that effects the concrete's performance. A well compacted concrete will be dense and will provide more strength.

2.5.7 Relative humidity

Hydration reaction stops if the concrete dries out or the temperature gets too low. The hydration reaction cannot progress in the absence of water. The relative humidity governs the overall presence of moisture content which governs the hydration rate of concrete and it ultimately effects the strength of concrete.

2.5.8 Temperature

Temperature is a major governing factor of hydration rate. With the increase in temperature, the rate of hydration reaction increases which results in faster gain in strength of concrete initially. However, the hydration rate is lesser when temperature is low and that is why the rate of gain of strength is also lesser. But the final strength of concrete will be higher in the case of lower temperature (Topcu 2005). This can be related to the fact that with slow rate of hydration, the hardened cement paste is well structured and is less permeable. So, must be kept in mind that we observe a similar but more definite effect of temperature on the concrete's porosity.

2.5.9 Curing

When concrete is placed in dry environment, the detrimental effects on strength of concrete can be reduced if proper curing is done. Curing is the process of controlling the rate and extent of moisture loss from concrete during the hydration process. Curing is done through many different processes including moist curing, air curing etc. For achieving desired strength curing must be done for a reasonable period of time. The curing period may depend on the properties requisite for the concrete, the purpose of its use, the ambient conditions and temperature of the surrounding atmosphere. Curing also control the temperature since this affects the rate at which cement hydrates. The common belief is that it takes concrete 28 days to cure and reach 100% of its strength (Goto 1991).

2.6 Optimized Concrete Mix

The concrete mixture optimization is very important for the overall performance of the concrete. One of the aspect of the concrete mix optimization is the usage of the locally available resources in fulfilling the engineering criteria as well as the economic needs.

The mixture proportion is the crucial factor in defining optimization factor as this will incorporate almost all the important factors like design economy and utilization of the local material.

As the construction process is becoming complex, the concrete design is also becoming more crucial. For the available mixture of aggregate there are three basic factors upon which we can optimize our mix proportions to meet our requirements.

If larger stone (increased coarse aggregate size) is used which is gap graded, the amount of voids will be larger as compared to the uniformly graded aggregate. These voids have to be filed by the mortar hence increasing its requirement. However, in the case of uniformly graded aggregate, the smaller voids are filled by the aggregate itself hence reducing the amount (volume) of voids to be filled by the mortar hence, reducing the mortar requirement in the concrete mix design.

Most of the volume of concrete consists of aggregate. The main properties of concrete like workability, permeability, durability and also the compressive and tensile strength depend upon the characteristics of the selected aggregates. We can define the grading of an aggregate as the amount of retainage or passing through a standard sieve size. The measure to achieve dense aggregate packing is the ideal grading curve, which describes the optimum grading for best concrete mixture and hence the concrete properties (Shilstone 1990). In order to achieve this ideal grading curve we have to take the appropriate amount of coarse aggregate and sand. So, the major objective is to figure out the amount of each constituent of aggregate. The mix design is specified on the basis of a particular water to cement ratio and the targeted strength.

In order to achieve higher compressive strength the role of smaller size aggregate is critical in a mix design. The notable thing is that particle size greater than 3/8” is effective for filling the major voids whereas particle in the range of No.8 to 3/8 helps in providing better workability of mixture (Soudki 2001).

There always exists an optimum combination for specified aggregates and their different gradations having lowest water to cement ratio and which produces higher compressive strengths. This optimized mixture produces consistent results with a suitable slump.

There must be a balance between the amount of coarse and fine aggregate, if we increase the amount of sand, the water demand of concrete mixture increases and the overall mixture becomes more sticky and to produce the required strength the cement demand increases. This increase in the amount of sand will require more pump pressure and will ultimately produce more crazing and finishing problems. If there is larger amount of inert coarse aggregate particles, then the mixture will become bony and this will also produce a different sort of finishing and placing problem. s The air content also affects the amount of required water in the mortar. Hence mortar is an important factor in determining the over-all water requirement for the concrete mix.

In actual Practice the dense packing of coarse and fine aggregate can give higher strengths. However we will face many construction, performance as well as the finishing problems if the mixture of aggregates is not well distributed. If the aggregates are not well graded then the requirement of filler i.e. mortar increases and this will ultimately affect the properties of whole concrete mix.

In short, we can say that by effectively utilizing the materials we can improve the economy, quality and durability of concrete along with reduction in the wasteful material.

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CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY

To achieve desired scope of the project, the project was decomposed into different, small and well defined tasks by keeping in view the nature and time duration allocated for that particular task. Project is mainly divided into two different phases. Each phase constitutes different tasks which are discussed in detail.

3.1.1 First Phase

In first phase of carrying out the project, material procurement was the major task. For this purpose, first of all, quantities of each concrete constituent were estimated according to the number of samples to be casted. Total 60 Cylinders were to be casted. The quantity estimate of each constituent is given in the table below.

CONSTITUENT	QUANTITY
Sand	130 kg
Coarse Aggregate	250 kg
Cement	65 kg

Table-4 Quantities Required

For the procurement of sand, samples from various different deposits were collected. They were oven dried for a day in oven. The FM test was conducted over them. We had to reject various samples as there results were not satisfying our desired FM requirement. The results of sand samples collected from the site near Motorway Chock, Islamabad were quite close to our FM requirements of 2.0 and 2.2. The origin of this sand was Hasan Abdal. In order to achieve exact FM, these samples were further graded in lab according to ASTM designation C-33.

For coarse aggregate, the required aggregate sizes were readily available. Since nominal maximum sizes were to be used in the mix design. Therefore, ASTM curves were consulted in order to achieve the specified ASTM grading. Cement of grade 53 was purchased from Best way Cement and water was readily available in laboratory.

3.1.2 Second Phase

After completion of first phase, core part of the project i.e. the casting phase started. Quantities were already estimated. Several different tests were performed on coarse and fine aggregates before casting different batches. Tests for specific gravity of sand, specific gravity for coarse aggregates, absorption capacity of both coarse and fine aggregates were carried out which are explained one by one.

3.1.2.1 Specific gravity and absorption of coarse aggregate

Specific gravity and absorption test for both types of coarse aggregates was conducted. The procedure and the results of the tests are given below:

A sample of 2 kg aggregate was used. It was thoroughly washed in order to remove any fine particle. Then it was submerged in clean, distilled water by placing it in a wired bucket at a room temperature of 25º C and made sure that entire aggregate sample is completely immersed in the bucket. For the next 24 hours, the aggregate and bucket should entirely be submerged in water.

Then we weighed the sample and the bucket while they were suspended in water. We took W1 as the suspended weight in water. For some time, we allowed drainage after the aggregate and bucket was removed from water. After that the aggregate was dried using absorbent clothes. Then the weight of empty bucket in water was taken as W2.

The entire film of water present over the aggregate was removed by using the absorbent clothes till the times that no water appeared on surface The saturated surface dried aggregate is then weighed as W3

Then the aggregate was placed in oven for next 24 hours. After that it was cooled and weighed. This weight is represented as W4.

W1= 1806 g

W2= 559 g

W3= 2020 g

W4= 2000 g

Specific gravity = W4 / (W4– (W1– W2)) = 2.65

Water Absorption = ((W3 – W4) / W4) X 100 = 1 %

3.1.2.2 Specific Gravity and absorption test for fine aggregate:

We prepared a sample of 1 kg sand passing through sieve number 4. Then we removed its moisture by placing it in the oven. Then it was cooled to normal handling temperature. After that we submerged sand in water completely at 25º C for next 24 hours. After that sample was dried using blower to achieve SSD condition. In order to achieve consistent drying we spread the sample on a non- absorbent, flat surface. The warm air of blower helps the drawing process.

With the change in sand type, we observed a slight change in specific gravity but mostly the values were around 2.65 to 2.7. We observed higher specific gravity for the fine aggregate as compare to coarse aggregate for a specific source or aggregate type. This can be related to the fact that more aggregate surface area is exposed as the particle size becomes smaller. Three different types of specific gravities can be computed for sand. Formula for computing bulk specific gravity is given by the following equation.

Bulk Specific Gravity = G_{sb} = A/ (B-C)

Where,

A = mass of oven-dry sample in air = 1000 g

B = mass of flask filled with water = 625 g

C = mass of flask filled with SSD sample & water = 1645 g

For our sample of sand the value of Bulk specific gravity was 2.67

3.1.2.3 Design Methodology

The design methodology for incorporating different constituents in concrete is based on the concept of Weighted Average Fineness Modulus (WAFM). It involves the contribution of FM of both types of aggregates and their respected volumes in such a way that their weighted average almost remains constant. The concept of WAFM comes from the ACI 211.1. The idea can be generated by looking at the table that it might be possible that ACI has kept WAFM constant for both types of aggregates so that their ratios change corresponding to each other in such a way that a constant number is obtained. **Adjust the volumes of coarse and fine aggregate such that their weighted average fineness modulus remains the same**.

The formula for WAFM is given below

- $Weighted\ Avg.\ FM = \frac{FMc \times Vc + FMs \times Vs}{Vc + Vs}$

Where,

FMc = Fineness modulus of coarse aggregate

Vc = Volume of coarse aggregate

FMs= Fineness modulus of fine aggregate

Vs = Volume of fine aggregate

Fineness Modulus of both aggregate types was calculated. Trend for bulk volume of coarse aggregate was observed from the ACI table 211.1. Trend for both aggregate types along with the WAFM is shown below:

	Aggregate Size: 1/2"				
FM	2	2.2	2.4	2.6	2.8
Bulk Coarse Agg vol.	X1={0.62, 0.63, 0.64}	X={0.60, 0.61, 0.62}	0.59	0.57	0.55
Fine Agg vol.	Y1	Y	0.306	0.317	0.328
WAFM	Z1	Z	5.10	5.106	5.116

Table-5 Trend for aggregate size ½ inch

From the above table it can be clearly seen that for Aggregate size of ½", WAFM almost remains constant across the table for a specific aggregate size against a particular FM of sand. Keeping this trend in mind we have to select one of the above mentioned bulk volume of coarse aggregates for which such a corresponding value of volume of fine aggregate can be achieved which when is incorporated in the formula of WAFM, yields the same constant number.

Here we are interested in the value of a particular X for which a corresponding Y can be achieved and the combination of both the volumes bring about maximum density and desired compressive and tensile strengths can then be achieved.

Graphical representation of this trend for aggregate size ½” is given below.

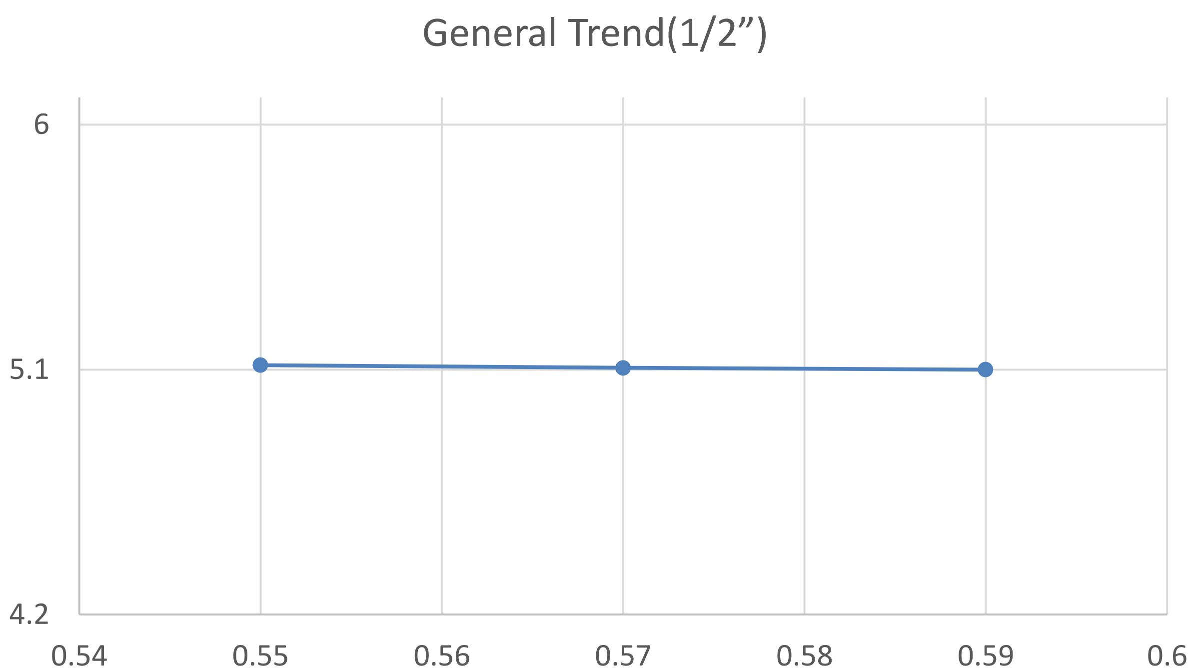


Figure-2 General trend Graphical representation for aggregate size ½ inch

The Figure clearly shows almost linear trend for WAFM against different values for bulk volume of coarse aggregate.

Similar trend is observed for coarse aggregate size 1”. Here too WAFM remains constant across the table. For a particular bulk volume of coarse aggregate a corresponding volume of fine aggregate is calculated and the value of WAFM still remains constant. As the FM of sand keeps on decreasing we have to increase the bulk volume of coarse aggregate so that the water demand is balanced. Table given on the next page clearly explains the linear trend of WAFM with the increase in bulk volume of coarse aggregate.

Here too, we are interested in the values of X for which corresponding Y can be calculated and then the WAFM is computed which almost remains constant. A value of bulk volume of coarse aggregate above and below that particular value is incorporated in the mix design for testing purposes.

The table for aggregate size 1” is given below. The trend of constant WAFM can be observed easily.

	Aggregate Size: 1"				
FM	2	2.2	2.4	2.6	2.8
Bulk Coarse Agg vol.	X1={0.74, 0.75, 0.76}	X={0.72, 0.73, 0.74}	0.71	0.69	0.67
Fine Agg vol.	Y1	Y	0.264	0.2755	0.287
WAFM	Z1	Z	6.118	6.101	6.090

Table-6 Trend for aggregate size 1 inch

We were interested in that particular value of bulk volume of coarse aggregate against FM 2.0 and 2.2 of sand for which we can get maximum strength and the desired slump. The Graphical trend for aggregate size is shown below which also shows linear behavior. For testing purposes, following the increasing trend, we used 0.72, 0.73 and 0.74 as the values of bulk volume of coarse aggregate against FM 2.2 of sand.

For sand of FM 2.0, values of bulk volume of coarse aggregate used were 0.74, 0.75 and 0.76. One of these values was recommended for mix design on the basis of maximum compressive and tensile strengths along with desired slump.

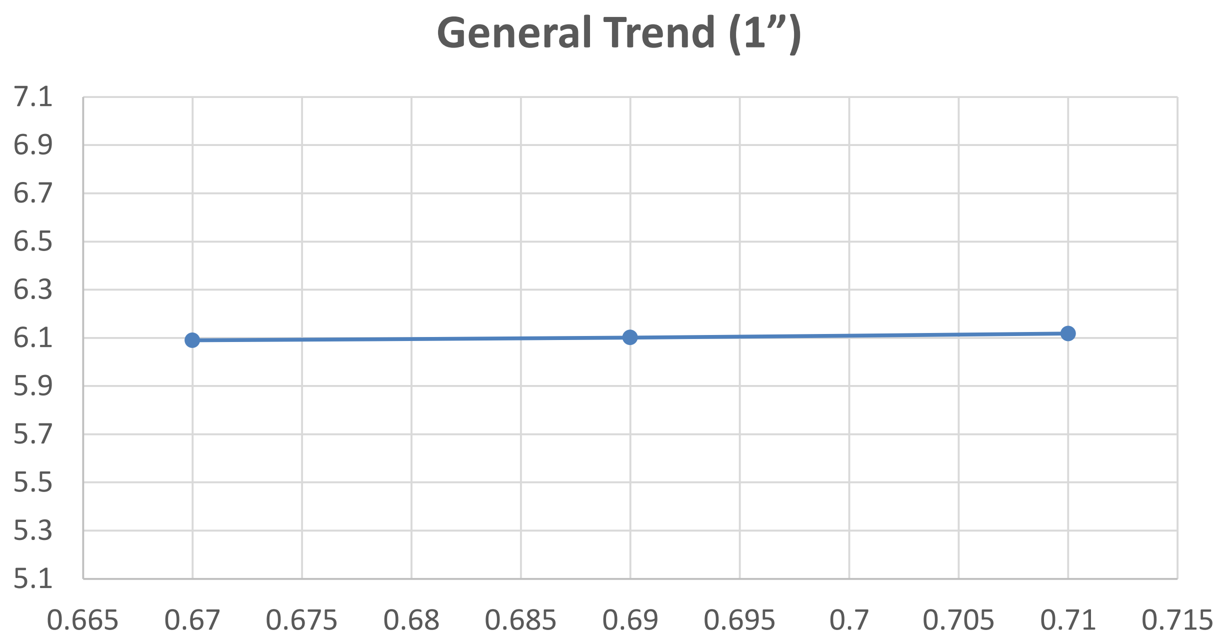


Figure-3 General trend Graphical representation for aggregate size 1 inch

As explained earlier, linear trend is also observed aggregate size 1”. This trend is extrapolated and value of bulk volume of coarse against which maximum strength and targeted workability is achieved is selected.

Once the mix design for all ratios was set, casting was done for each ratio. A total of 12 batches were casted. Each batch comprised of 5 cylinders. 3 of these cylinders were casted for compressive strength test and 2 for split tensile test.

The mixing regime followed in concrete mix is given below:

- Target Strength = 4000 Psi
- Water-cement ratio= 0.55
- Nominal size of coarse aggregate = ½” and 1”
- FM of sand= 2.0 & 2.2

The distribution of total number of cylinders of 12 different batches is explained by the following table.

	FM =2.2					**FM=2.0**		
	Bulk vol. of coarse Aggregate				Bulk vol. of coarse Aggregate			
Agg Size:1/2"	0.6	0.61	0.62		Agg Size:1/2"	0.62	0.63	0.64
Cylinders	5	5	5		Cylinders	5	5	5
Total	**15**				**15**			
Agg Size:1"	0.72	0.73	0.74		Agg Size:1"	0.74	0.75	0.76
Cylinders	5	5	5		Cylinders	5	5	5
Total	**15**				**15**			

Table-7 Cylinders for each syndicate

These cylinders were tested after 28 days for compression and tensile strengths. Details of the test results for each batch and selection of a particular ratio on the basis of certain parameters is discussed in detail in next chapter.

CHAPTER 4

RESULTS

4.1 OVERVIEW

In order to fulfill the scope of the project, Compression Test, Split Tensile Test and Slump Test were performed on every batch. The Compression Tests were performed on 4" x 8" (100 mm x 200 mm) cylinders while Split Tensile Tests were performed on 6" x 12" (150 mm x 300 mm) cylinders. For Compression Tests, the Compression Testing Machine was used and for Split Tensile Tests, Flexure Testing Machine was used. While the slump tests were performed on Los Angeles Apparatus. The results were compiled after performing these tests. The summary of results is given in the following paragraph.

4.2 Detailed Summary

Results for every cylinder were noted and are compiled in the following tables. There were five cylinders in each batch .Three were tested for Compression Test and Two for Split Tensile Test.

Compression Test were done on 4" x 8" (100 mm x 200 mm) cylinders while Split Tensile Tests were performed on 6" x 12" (150 mm x 300 mm) cylinders.

There were total of sixty Cylinders. In each batch there are five cylinders i.e., there are total twelve batches. These batches are sub-categorized under 'Syndicates'. Each syndicate consist of three batches. So there are total four syndicated.

Syndicate	Batch	FM of Sand	Aggregate Size
1	1-3	2.2	½"
2	4-6	2.0	½"
3	7-9	2.2	1"
4	10-12	2.0	1"

Table-8 Division of syndicates

4.2.1 Compression Test

Compression test was done through compression testing machine with the loading rate of 0.25 MPa

Figure-4 Compression Test

4.2.2 Split Tensile Test

Split Tensile test was done through Flexure machine with the loading rate of 0.025 MPa

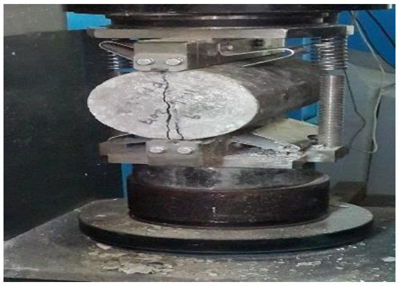


Figure-5 Split Tensile Test

4.2.3 Slump Test

Slump Test was done using Los Angeles Apparatus

Figure-6 Slump Test

4.3 Batch Results

Batch Number: _______1_________

Max Nominal Size of CA: _____1/2"___ **Volume of Dry Rodded CA: ____0.60___**

Fineness Modulus of Sand: ___2.2_____ **Slump of Concrete: ____2.5"______**

Cylinders For:	**Sample #**	**Size**		**Weight (Kg)**	**Compression**		**Tension**	
		Dia (mm)	**Height (mm)**		**Ultimate Load(KN)**	**Stress (N/mm²)**	**Ultimate Load(KN)**	**Stress (N/mm²)**
Compression Testing	1	100	200		237.34	30.22		
	2	100	200		205.66	26.186		
	3	100	200		229.1	29.17		
Tensile Testing	4	150	300				176	2.49
	5	150	300				167.53	2.37

Table-9 batch 1

Batch Number: _______2_________

Max Nominal Size of CA: _____1/2"___ **Volume of Dry Rodded CA: ____0.61___**

Fineness Modulus of Sand: ___2.2_____ **Slump of Concrete: ____3"______**

Cylinders For:	**Sample #**	**Size**		**Weight (Kg)**	**Compression**		**Tension**	
		Dia (mm)	**Height (mm)**		**Ultimate Load(KN)**	**Stress (N/mm²)**	**Ultimate Load(KN)**	**Stress (N/mm²)**
Compression Testing	1	100	200		226.74	28.87		
	2	100	200		246.85	31.43		
	3	100	200		208.76	26.58		
Tensile Testing	4	150	300				184.5	2.61
	5	150	300				174.6	2.47

Table-10 batch 2

Batch Number: _______3_________

Max Nominal Size of CA: _____1/2"___

Volume of Dry Rodded CA: ____0.62___

Fineness Modulus of Sand: ___2.2_____

Slump of Concrete: ____3.5"______

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm^2)	Ultimate Load(KN)	Stress (N/mm^2)
Compression Testing	1	100	200		160.22	20.4		
	2	100	200		176.71	22.5		
	3	100	200		183.78	23.4		
Tensile Testing	4	150	300				152.68	2.16
	5	150	300				161.16	2.28

Table-11 batch 3

Batch Number: _______4_________

Max Nominal Size of CA: _____1/2"___

Volume of Dry Rodded CA: ____0.62___

Fineness Modulus of Sand: ___2.0_____

Slump of Concrete: ____3"______

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm^2)	Ultimate Load(KN)	Stress (N/mm^2)
Compression Testing	1	100	200		198.3	25.3		
	2	100	200		174	22.1		
	3	100	200		210.3	26.8		
Tensile Testing	4	150	300				180	2.5465
	5	150	300				164	2.32

Table-12 batch 4

Batch Number: _______5_________

Max Nominal Size of CA: _____1/2"___ **Volume of Dry Rodded CA: ____0.63___**

Fineness Modulus of Sand: ___2.0_____ **Slump of Concrete: ____3.5"______**

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm²)	Ultimate Load(KN)	Stress (N/mm²)
Compression Testing	1	100	200		237.1	30.2		
	2	100	200		210	27		
	3	100	200		206.5	26.3		
Tensile Testing	4	150	300				191	2.7021
	5	150	300				169	2.391

Table-13 Batch 5

Batch Number: _______6_________

Max Nominal Size of CA: _____1/2"___ **Volume of Dry Rodded CA: ____0.64___**

Fineness Modulus of Sand: ___2.0_____ **Slump of Concrete: ____3.5"______**

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm²)	Ultimate Load(KN)	Stress (N/mm²)
Compression Testing	1	100	200		170.9	21.76		
	2	100	200		181.9	23.16		
	3	100	200		207.11	26.37		
Tensile Testing	4	150	300				159.75	2.26
	5	150	300				155.89	2.2054

Table-14 Batch 6

Batch Number: _______7_________

Max Nominal Size of CA: _____1"___ **Volume of Dry Rodded CA: ____0.72___**

Fineness Modulus of Sand: ___2.2_____ **Slump of Concrete: ____3.5"______**

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm²)	Ultimate Load(KN)	Stress (N/mm²)
Compression Testing	1	100	200		150.8	19.2		
	2	100	200		168.07	21.4		
	3	100	200		159.44	20.3		
Tensile Testing	4	150	300				164	2.32
	5	150	300				148	2.093

Table-15 batch 7

Batch Number: _______8_________

Max Nominal Size of CA: _____1"___ **Volume of Dry Rodded CA: ____0.73___**

Fineness Modulus of Sand: ___2.2_____ **Slump of Concrete: ____3.5"______**

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm²)	Ultimate Load(KN)	Stress (N/mm²)
Compression Testing	1	100	200		162.58	20.7		
	2	100	200		167.132	21.28		
	3	100	200		171.22	21.8		
Tensile Testing	4	150	300				156.57	2.215
	5	150	300				159.4	2.255

Table-16 batch 8

Batch Number: _______9_________

Max Nominal Size of CA: _____1"___ **Volume of Dry Rodded CA: ____0.74___**

Fineness Modulus of Sand: ___2.2_____ **Slump of Concrete: ____4"______**

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm²)	Ultimate Load(KN)	Stress (N/mm²)
Compression Testing	1	100	200		168.07	21.4		
	2	100	200		171.06	21.78		
	3	100	200		168.86	21.5		
Tensile Testing	4	150	300				2.42	350.77
	5	150	300				2.574	373.34

Table-17 Batch 9

Batch Number: _______10_________

Max Nominal Size of CA: _____1"___ **Volume of Dry Rodded CA: ____0.74___**

Fineness Modulus of Sand: ___2.0_____ **Slump of Concrete: ____3"______**

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm²)	Ultimate Load(KN)	Stress (N/mm²)
Compression Testing	1	100	200		131.94	16.8		
	2	100	200		135.87	17.3		
	3	100	200		150.8	19.2		
Tensile Testing	4	150	300				160.45	2.27
	5	150	300				174.6	2.47

Table-18 batch 10

Batch Number: _______11_________

Max Nominal Size of CA: _____1”___ **Volume of Dry Rodded CA: ____0.75___**

Fineness Modulus of Sand: ___2.0_____ **Slump of Concrete: ____3.5”______**

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm^2)	Ultimate Load(KN)	Stress (N/mm^2)
Compression Testing	1	100	200		154.49	19.67		
	2	100	200		189.28	24.1		
	3	100	200		174.09	22.2		
Tensile Testing	4	150	300				170.35	2.41
	5	150	300				174.6	2.47

Table-19 Batch 11

Batch Number: _______12_________

Max Nominal Size of CA: _____1”___ **Volume of Dry Rodded CA: ____0.76___**

Fineness Modulus of Sand: ___2.0_____ **Slump of Concrete: ____4”______**

Cylinders For:	Sample #	Size		Weight (Kg)	Compression		Tension	
		Dia (mm)	Height (mm)		Ultimate Load(KN)	Stress (N/mm^2)	Ultimate Load(KN)	Stress (N/mm^2)
Compression Testing	1	100	200		176.715	22.5		
	2	100	200		168.08	21.4		
	3	100	200		180.64	23		
Tensile Testing	4	150	300				173.533	2.455
	5	150	300				176.36	2.495

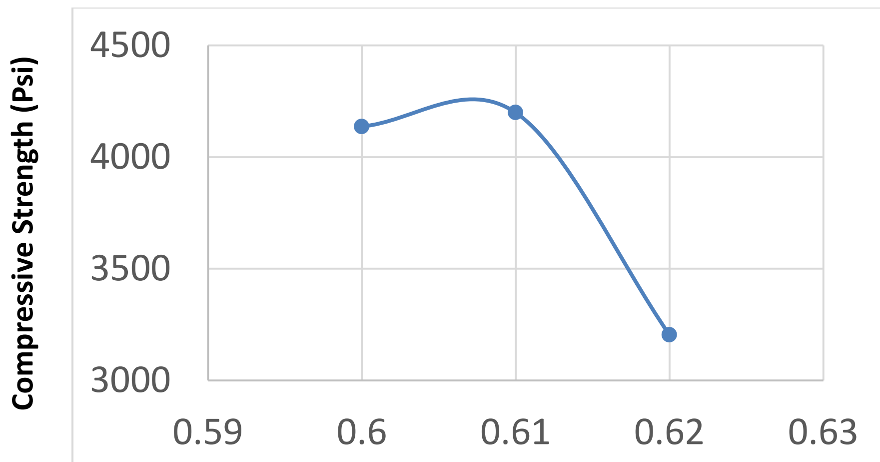
Table-20 Batch 12

4.2.1 Summary

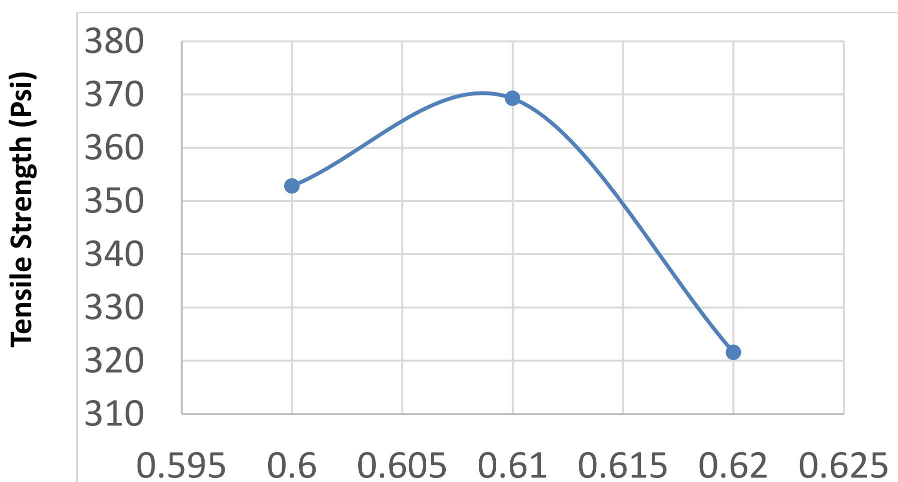
Syndicate # 1 **(**FM=2.2, Aggregate size = ½”**)**

Coarse Agg. Bulk Vol	**Nominal Coarse Aggregate size**	**Slump**	**Age**	**Avg. weight**	**Avg Density**	**Avg. Failure Load**	**Avg. Compressive Strength**	**Avg Tensile Strength**
Per Unit	in	in	Days	kg	kg/m^3	kN	Psi	Psi
0.60	1/2"	2"	28	3.647	2322	194.2	4136.85	352.83
0.61	*1/2"*	*3"*	*28*	*3.653*	*2324*	*217.87*	*4199.2*	*369.247*
0.62	1/2"	3"	28	3.638	2311	186.5	3204.5	321.57

Table-21 Syndicate 1



Bulk volume Figure-7 Comp. strength Syndicate 1



Bulk volume Figure -8 Tensile strength Syndicate 1

Syndicate # 2 **(**FM= 2.0, Aggregate Size = ½”**)**

Coarse Agg Bulk Vol.	**Nominal Coarse Aggregate size**	**Slump**	**Age**	**Avg. Weight**	**Avg. Density**	**Avg. Failure Load**	**Avg. Compressive Strength**	**Avg. Tensile Strength**
Per Unit	in	in	Days	kg	kg/m^3	kN	Psi	Psi
0.62	1/2"	3"	28	3.683	2314.5	224.47	3585.85	355.08
0.63	1/2"	3.5"	28	3.691	2321.9	227.43	4035.35	373.05
0.64	1/2"	3.5"	28	3.67	2307.7	176.34	3445.2	323.98

Table-22 Syndicate 2

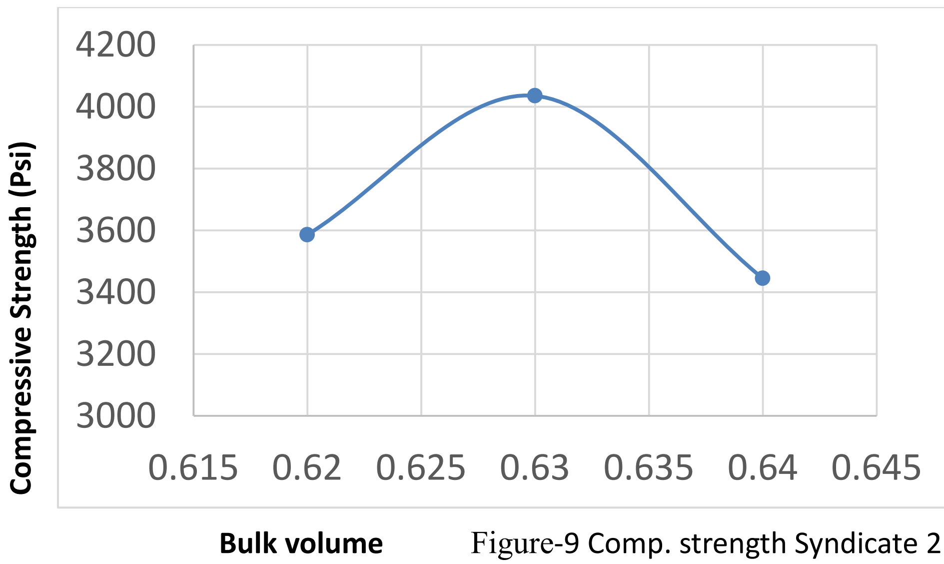


Figure-9 Comp. strength Syndicate 2

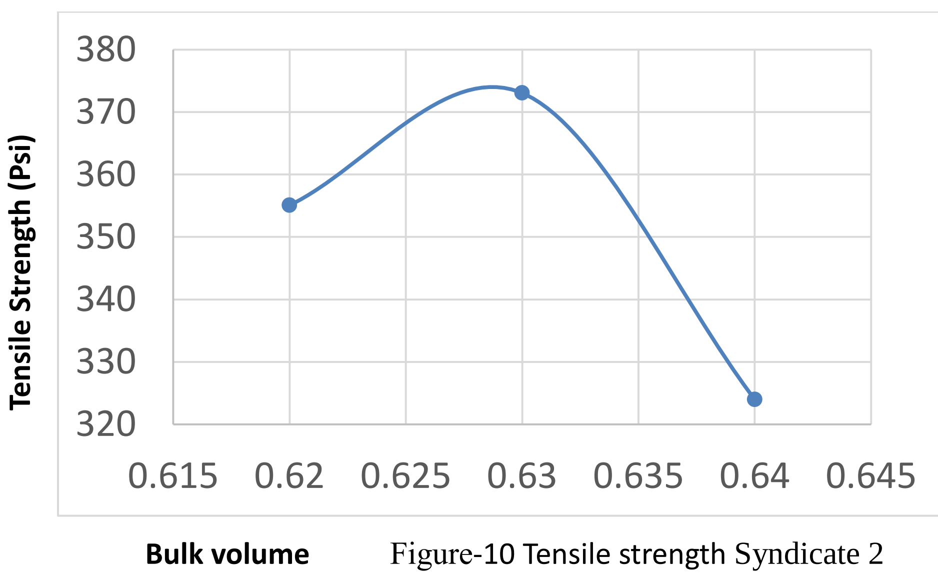
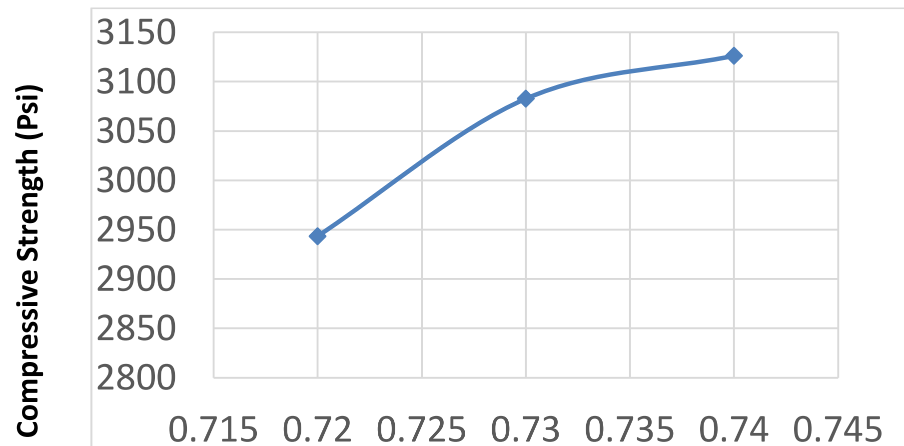


Figure-10 Tensile strength Syndicate 2

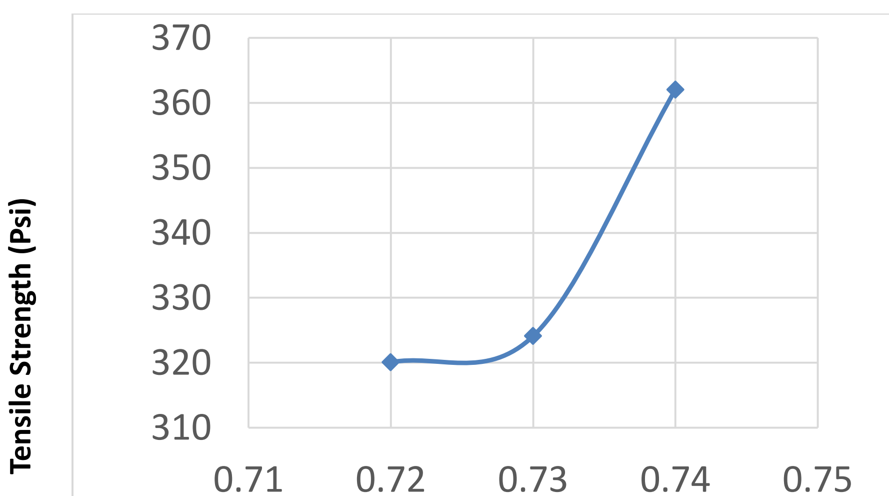
Syndicate # 3 **(**FM= 2.2, Aggregate Size =1”**)**

Coarse Agg Bulk Vol.	**Nominal Coarse Aggregate size**	**Slump**	**Age**	**Avg. weight**	**Avg Density**	**Avg. Failure Load**	**Avg. Compressive Strength**	**Avg. Tensile Strength**
Per Unit	in	in	Days	kg	kg/m^3	kN	Psi	Psi
0.72	1”	3.5"	28	3.642	2316.39	159.53	2943.5	320.08
0.73	1"	3.5"	28	3.650	2321.48	165.09	3082.7	324.11
0.74	1"	4”	28	3.653	2324.26	186.5	3126.2	362.05

Table-23 Syndicate 3



Bulk volume Figure-11 Comp. strength Syndicate 3

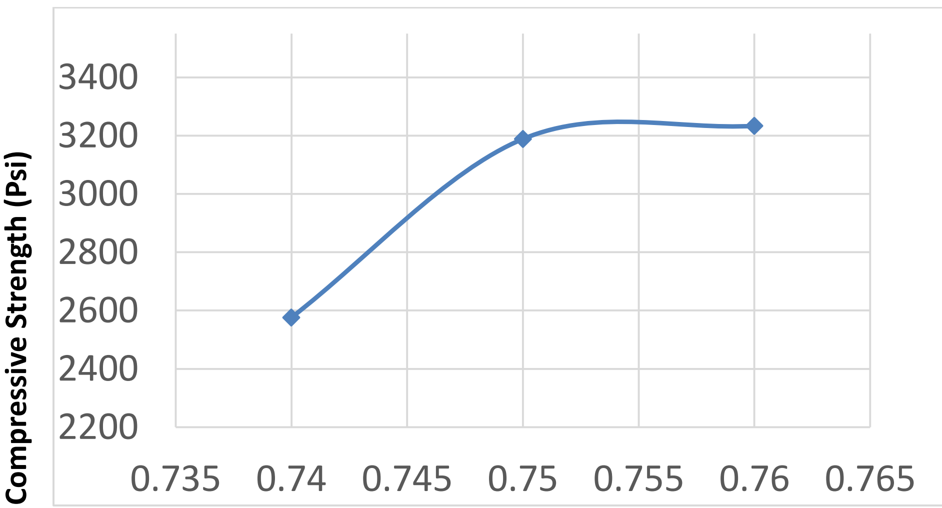


Bulk volume Figure-12 Tensile strength Syndicate 3

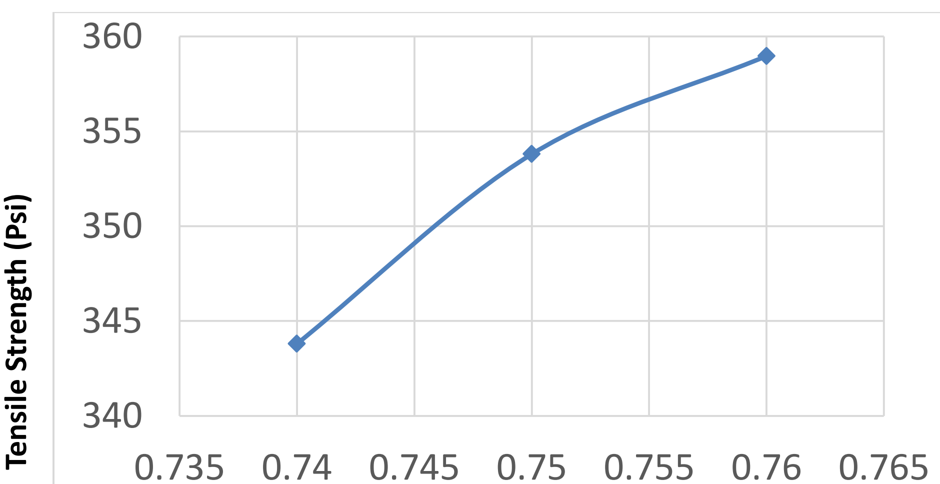
***Syndicate # 4 (**FM= 2.0, Aggregate Size =1”**)**

Coarse Agg Bulk Vol.	**Nominal Coarse Aggregate size**	**Slump**	**Age**	**Avg. weight**	**Avg Density**	**Avg. Failure Load**	**Avg. Compressive Strength**	**Avg. Tensile Strength**
Per Unit	in	in	Days	kg	kg/m^3	kN	Psi	Psi
0.74	1”	3"	28	3.651	2322.40	139.43	2576.215	343.8
0.75	1"	3"	28	3.653	2324.25	172.64	3188.55	353.8
0.76	1"	3.5"	28	3.658	2328.87	186.5	3233.5	358.97

Table-24 Syndicate 4



Bulk volume Figure-13 Comp. strength Syndicate 4



Bulk volume Figure-14 Tensile strength Syndicate 4

CHAPTER 5

CONCLUSIONS

5.1 OVERVIEW

In this chapter we will be discussing the deductions we made and conclusions we drew from our results. The detailed summary of the result is already provided under section “4.2 Detailed Summary”. The results we found were in accordance with earlier researches made.

5.2 Summary:

For syndicate 1 we obtained maximum values of compressive and tensile strength against coarse aggregate bulk volume of 0.61.From this, we can conclude that for the design against FM 2.2 and aggregate size of ½inches, suitable bulk volume value is of 0.61. Here the slump was around 3 inches which is an appropriate value. The Figure-7, Figure-8 are depicting results for this very syndicate.

Similarly we obtained maximum strength for syndicate 2 at the coarse aggregate bulk volume of 0.63.That mean for Aggregate ½” and FM of 2.0 apposite value of bulk volume is 0.63. Here a suitable slump of 3” was achieved. In the results of syndicate 2 we also observed a slight decrease in strength which can be related to the decrease in Fineness Modulus of sand. This is due to the fact that when the fineness modulus decreases, more voids are created in the concrete mixture which are to be filled by the cement paste mixture (mortar).This results in reduction in concrete density. This ultimately results in reduction of the strength of overall concrete mixture. The Figure-9, Figure-10 are illustrating the outcomes of syndicate 2.

In the case of syndicate 3, we achieved maximum values of strength against coarse aggregate bulk volume of 0.74.A perfect slump of 3.5 inches was attained in this case. From this, we can conclude that the design against FM 2.2 and aggregate size of 1 inches, appropriate bulk volume is 0.74. The Figure-11, Figure-12 are showing the results of syndicate 3

Similarly, for syndicate 4 i.e., for aggregate size of 1 inch and fineness modulus of 2.0, maximum compressive and tensile strength values were attained at the coarse aggregate bulk volume of 0.76. Here slump jumped to 4 inches. We observed an increase in slump. This is due to increase in the size of coarse aggregate. As we all know that with the increase in the size of an aggregate, the effective surface area decreases and hence it requires less water for it surface absorption and surface wetting. Consequently this leave behind more water for the rest of the concrete mixture. That's the reason why we obtained more slump in the case of syndicate 4.The results for syndicate are represented in Figure-13, Figure-14.

Moreover, we can also observe decrease in overall compressive and tensile strength of concrete. This is due to the fact that with the increase in aggregate size there is a decrease in the strength. In case of larger aggregate size, the Interfacial Transition Zone (ITZ) formed is also larger, which is the weak link in the concrete. This increased size of ITZ results in reduction of overall concrete strength. We witnessed bleeding in the case of syndicate 4. The reduction in strength can also be related to this bleeding phenomenon which increases with increase in the coarse aggregate size.

References

1. Kozul, R., & Darwin, D. (1997). Effects of aggregate type, size, and content on concrete strength and fracture energy. University of Kansas Center for Research, Inc.
2. Concrete technology by M.S Shetty 5th edition.
3. Concrete technology by J.J Brooks, Pearson publication.
4. Abdullahi (2012), "Effect of aggregate type on Compressive strength of concrete", International Journal of Civil and Structural Engineering"
5. Bhikshma, V. & Florence ,G. A. (2013), "Studies on effect of maximum size of aggregate in higher grade concrete with high volume fly ash", Asian Journal of Civil Engineering.
6. Shilstone, J. S. (1990). Concrete mixture optimization. Concrete International, 12(6), 33-39.
7. Goto, S., & Roy, D. M. (1981). The effect of w/c ratio and curing temperature on the permeability of hardened cement paste. Cement and Concrete
8. Topcu, I. B., & Toprak, M. U. (2005). Fine aggregate and curing temperature effect on concrete maturity. Cement and Concrete
9. Buenfeld, N. R., & Okundi, E. (1998). Effect of cement content on transport in concrete. Magazine of Concrete
10. Kumar, R. P.1 & Krishna, R.M.V. (2012), "A Study on the Effect of Size of Aggregate on the Strength and Sorptivity Characteristics of Cinder Based Light Weight Concrete"

11. Design and Control of Concrete Mixtures, First Issue, Portland Cement Association.
12. V.R.K. Narasinha Raju1 and T. Appa Reddy, (2009),” Workability and Strength characteristics of Cement Concrete with Partial Replacement of River Sand by Manufactured Fine aggregate”
13. https://www.nbmcw.com/concrete/582-effect-of-fineness-of-sand-on-the-cost-and-properties-of-concrete.html
14. http://www.lafarge-na.com/wps/portal/na/en/3_A_11_12-The_Effect_of_Aggregate_Gradation_and_Fineness_on_Concrete_Properties
15. https://theconstructor.org/practical-guide/fineness-modulus-method-of-concrete-mix-design/7214/
16. http://iti.northwestern.edu/cement/monoFigure/MonoFigure5_5_2.html
17. https://www.slideshare.net/alpenaccedu/con-124-session-1-introduction-15676426
18. http://www.engr.psu.edu/ce/courses/ce584/concrete/library/materials/aggregate/aggregatesmain.htm